WHAT IS CLAIMED IS:

1. An optical waveguide comprising:

a dielectric core region extending along a waveguide axis; and

a dielectric confinement region surrounding the core about the waveguide axis, the confinement region comprising a photonic crystal structure having a photonic band gap, wherein during operation the confinement region guides EM radiation in at least a first range of frequencies to propagate along the waveguide axis,

wherein the core has an average refractive index smaller than about 1.3 for a frequency in the first range of frequencies,

wherein the core has a diameter in a range between about 4λ and 80λ, wherein λ is a wavelength corresponding to a central frequency in the first frequency range, and

wherein the dielectric confinement region extends transversely from the core for at least a distance of about 6λ.

2. The waveguide of claim 1, wherein the dielectric confinement region extends transversely from the core for at least a distance of about 10λ.

3. The waveguide of claim 1, wherein the average refractive index of the core is smaller than about 1.2 for a frequency in the first range of frequencies.

4. The waveguide of claim 1, wherein the average refractive index of the core is smaller than about 1.1 for a frequency in the first range of frequencies.

5. The waveguide of claim 1, wherein the core comprises a gas.

6. The waveguide of claim 1, wherein the first range of frequencies corresponds to wavelengths in the range of about 1.2 microns to 1.7 microns.

7. The waveguide of claim 1, wherein the first range of frequencies corresponds to wavelengths in the range of about 0.7 microns to 0.9 microns.

8. The waveguide of claim 1, wherein the ratio of the bandwidth of the first range of frequencies and the central frequency and is at least about 10%.

9. The waveguide of claim 1, wherein the waveguide axis is straight.

10. The waveguide of claim 1, wherein the core has a circular cross-section.

11. The waveguide of claim 1, wherein the core has a hexagonal cross-section.

12. The waveguide of claim 1, wherein the core has a rectangular cross-section.

13. The waveguide of claim 1, wherein the confinement region guides at least one mode to propagate along the waveguide axis with radiative losses less than 0.1 dB/km for a frequency in the first range of frequencies.

14. The waveguide of claim 13, wherein the confinement region guides at least one mode to propagate along the waveguide axis with radiative losses less than 0.01 dB/km for a frequency in the first range of frequencies.

15. The waveguide of claim 13, wherein the mode is a TE mode.

16. The waveguide of claim 1, wherein the waveguide supports a mode in which at least 99% of the average energy of the propagating EM radiation is in the core for a frequency in the first range of frequencies.

17. The waveguide of claim 16, wherein the mode is a TE mode.

18. The waveguide of claim 1, wherein the confinement region comprises at least two dielectric materials having different refractive indices.

19. The waveguide of claim 18, wherein the ratio of the refractive index of the higher index dielectric material to that of the lower index dielectric material is greater than 1.1.

20. The waveguide of claim 19, wherein the ratio of the refractive index of the higher index dielectric material to that of the lower index dielectric material is greater than 1.5.

21. The waveguide of claim 20, wherein the ratio of the refractive index of the higher index dielectric material to that of the lower index dielectric material is greater than 2.

22. The waveguide of claim 1, wherein the photonic bandgap is an omnidirectional photonic bandgap.

23. The waveguide of claim 1, wherein the photonic bandgap is sufficient to cause EM radiation that is incident on the confinement region from the core in the first frequency range and with any polarization to have a reflectivity for a planar geometry that is greater than 95% for angles of incidence ranging from 0° to at least 80°.

24. The waveguide of claim 1 wherein the photonic crystal is a two-dimensional photonic crystal.

25. The waveguide of claim 1 wherein the photonic crystal is a one-dimensional photonic crystal.

26. The waveguide of claim 18, wherein the confinement region comprises alternating layers of the two dielectric material surrounding the core about the waveguide axis.

27. The waveguide of claim 26, wherein the refractive indices and thicknesses of at least some of the alternating dielectric layers substantially satisfy the following equality:

$$\frac{d_{hi}}{d_{lo}} = \frac{\sqrt{n_{lo}^2 - 1}}{\sqrt{n_{hi}^2 - 1}}$$

where d_{hi} and d_{lo} are the thicknesses of adjacent higher-index and lower-index layers, respectively, and n_{hi} and n_{lo} are the refractive indices of the adjacent higher-index and lower-index layers, respectively.

28. The waveguide of claim 26, wherein the confinement region comprises at least 12 pairs of the alternating layers.

29. The waveguide of claim 26, wherein the waveguide supports at least one mode propagating along the waveguide axis for which the confinement region comprises a sufficient number of pairs of alternating layers to limit radiative losses of the mode to less than 0.1 dB/km for a frequency in the first range of frequencies.

30. The waveguide of claim 26, wherein the waveguide supports at least one mode propagating along the waveguide axis for which the confinement region comprises a sufficient number of pairs of alternating layers to limit radiative losses of the mode to less than 0.01 dB/km for a frequency in the first range of frequencies.

31. The waveguide of claim 18, wherein the lower-index dielectric material comprises a polymer or a glass.

32. The waveguide of claim 18, wherein the higher-index dielectric material comprises germanium, tellurium, or a chalcogenide glass.

33. The waveguide of claim 1, wherein the diameter of the core is in the range of about 8λ and 80λ.

34. The waveguide of claim 1, wherein the diameter of the core is in the range of about 4λ and 60λ.

35. The waveguide of claim 1, wherein the diameter of the core is in the range of about 5λ and 60λ.

36. The waveguide of claim 1, wherein the diameter of the core is in the range of about 6λ and 40λ.

37. The waveguide of claim 1, wherein the diameter of the core is in the range of about 8λ and 40λ.

38. An optical telecommunications system comprising:

a transmitter generating an optical signal; and

the optical waveguide of claim 1 coupled at one end to the transmitter to carry the optical signal, wherein the optical signal is at a frequency in the first frequency range.

39. The system of claim 38, wherein the optical waveguide has a length greater than 30 km.

40. The system of claim 38, wherein the optical waveguide has a length greater than 200 km.

41. The system of claim 38, wherein the optical waveguide has a length greater than 500 km.

42. The system of claim 39 further comprising an optical receiver coupled to the other end of the optical waveguide to detect the optical signal.

43. The system of claim 39 further comprising an optical amplifier coupled to the other end of the optical waveguide to amplify the optical signal.

44. The system of claim 39 further comprising an optical regenerator coupled to the other end of the optical waveguide to regenerate the optical signal as an electrical signal.

45. The system of claim 39 further comprising a dispersion compensation module coupled to the other end of the optical waveguide to introduce dispersion to the optical signal that substantially cancels dispersion caused by the optical waveguide.

46. The system of claim 38, wherein the optical signal is at a wavelength in the range of about 1.2 microns to about 1.7 microns.

47. The system of claim 38, wherein the optical signal is at a wavelength in the range of about 0.7 microns to about 0.9 microns.

48. The system of claim 38, wherein the transmitter generates multiple signals at different wavelengths, and wherein the different wavelengths correspond to frequencies in the first frequency range.

49. The waveguide of claim 1, wherein at least a first end of the waveguide includes a coupling segment over which the refractive index cross-section is continuously varied.

50. The waveguide of claim 49, wherein the refractive index cross-section is continuously varied to alter the field profile of a working mode.

51. The waveguide of claim 1 further comprising a second waveguide coupled to the first mentioned waveguide, wherein the cross-section of the second waveguide adjacent the first waveguide comprises regions of doped silicon located to improve coupling of the working mode into the second waveguide.

52. The waveguide of claim 1 further comprising a second waveguide coupled to the first mentioned waveguide, wherein the cross-section of the second waveguide adjacent the first waveguide comprises a hollow ring contacting the dispersion tailoring region of the first waveguide to thereby improve coupling of a working mode into the second waveguide.

53. An optical waveguide comprising:

a dielectric core region extending along a waveguide axis; and

a dielectric confinement region surrounding the core about the waveguide axis, the confinement region having an average index greater than that of the core, wherein during operation the confinement region guides EM radiation in at least a first range of frequencies to propagate along the waveguide axis,

wherein the core has an average refractive index smaller than about 1.3 for a frequency in the first range of frequencies,

wherein the core has a diameter in a range between about 4λ and 80λ, wherein λ is a wavelength corresponding to a central frequency in the first frequency range, and

wherein the dielectric confinement region extends transversely from the core for at least a distance of about 6λ

54. The waveguide of claim 53, wherein the dielectric confinement region extends transversely from the core for at least a distance of about 10λ.

55. The waveguide of claim 53, wherein the dielectric confinement region comprises at least two dielectric materials have refractive indices that differ by at least 10%.

56. The waveguide of claim 53, wherein the core a diameter in a range between about 6λ and 60λ.

57. An optical waveguide comprising:

a dielectric core region extending along a waveguide axis; and

a dielectric confinement region surrounding the core about the waveguide axis, the confinement region comprising alternating layers of at least two dielectric two materials surrounding the core about the waveguide axis, the two dielectric materials having refractive indices that differ by at least 10%, wherein during operation the confinement region guides EM radiation in at least a first range of frequencies to propagate along the waveguide axis,

wherein the core has an average refractive index smaller than about 1.3 for a frequency in the first range of frequencies,

wherein the core has a diameter in a range between about 4λ and 80λ, wherein λ is a wavelength corresponding to a central frequency in the first frequency range, and

wherein the dielectric confinement region extends transversely from the core for at least a distance of about 6λ.

58. The waveguide of claim 57, wherein the dielectric confinement region extends transversely from the core for at least a distance of about 10λ.

59. The waveguide of claim 57, wherein the core a diameter in a range between about 6λ and 60λ.

60. An optical waveguide comprising:

a dielectric core region extending along a waveguide axis; and

a dielectric confinement region surrounding the core about the waveguide axis, the confinement region comprising at least 12 pairs of alternating layers of dielectric material having different refractive indices, the layers sufficient to guide EM radiation in at least a first range of frequencies to propagate along the waveguide axis,

wherein the refractive indices of the alternating layers differ by at least 10% for a frequency in the first range of frequencies,

wherein at least some of the pairs of alternating layers have a total thickness equal to about a, and

wherein the core has a diameter in a range between about $10a$ and $100a$.

61. The waveguide of claim 60, wherein the core has an average refractive index smaller than about 1.3 for a frequency in the first range of frequencies.

62. The waveguide of claim 60, wherein the core diameter is in a range between about $20a$ and $100a$.

63. An optical waveguide comprising:

a dielectric core region extending along a waveguide axis; and

a dielectric confinement region surrounding the core about the waveguide axis, the confinement region guiding EM radiation in at least a first range of frequencies to propagate along the waveguide axis,

wherein the core has an average refractive index smaller than about 1.3 for a frequency in the first range of frequencies, and

wherein the core has a diamater in a range between about 5 microns and 170 microns.

64. The waveguide of claim 63, wherein the core has a diamater in a range between about 7 microns and 100 microns.

65. The waveguide of claim 63, wherein the core has a diamater in a range between about 10 microns and 100 microns.

66. An optical waveguide comprising:

a dielectric core region extending along a waveguide axis; and

a dielectric confinement region surrounding the core about the waveguide axis, the confinement region comprising at least two dielectric materials forming a photonic crystal structure having a photonic band gap, the dielectric materials sufficient to guide EM radiation in at least a first range of frequencies to propagate along the waveguide axis,

wherein the refractive indices of the dielectric materials in the confinement region differ by at least 10% for a frequency in the first range of frequencies, and

wherein the core has a diameter in a range between about 5 microns and 170 microns.

67. The waveguide of claim 66, wherein the core has a diamater in a range between about 7 microns and 100 microns.

68. The waveguide of claim 66, wherein the core has a diamater in a range between about 10 microns and 100 microns.

69. A method of designing a photonic crystal optical waveguide including a dielectric core region extending along a waveguide axis and a dielectric confinement region surrounding the core about the waveguide axis, wherein the confinement region is configured to guide EM radiation in at least a first range of frequencies to propagate along the waveguide axis and wherein the core has an average refractive index smaller than about 1.3 for a frequency in the first range of frequencies, the method comprising:

selecting a transverse dimension for the core based on one or more design criteria for the guided EM radiation including mode separation, group-velocity dispersion, radiative losses, absorption losses, and cladding nonlinearity suppression.

70. The method of claim 69, wherein the transverse dimension for the core is based on at least two of the design criteria.

71. The method of claim 70, wherein an upper limit for the transverse dimension of the core is selected based on the mode separation, and wherein a lower limit for the transverse dimension is selected based on at least one of the group-velocity dispersion, the radiative losses, the absorption losses, and the cladding nonlinearity suppression.

72. The method of claim 69, wherein the confinement region comprises at least two dielectric materials having different refractive, and wherein the method further comprises:

selecting an index contrast for the different refractive indices based on at least one of the design criteria including the radiative losses, the absorption losses, and the cladding nonlinearity suppression.